

electric materials. Despite their high performance levels, $(1-x)[\text{Pb}(\text{Zn}_{1/3}\text{Nb}_{2/3})\text{O}_3]:x[\text{PbTiO}_3]$ materials have found limited use until now because, relative to previously commercially available piezoelectric materials, they tend to be much more fragile.

What has made it feasible to incorporate $(1-x)[\text{Pb}(\text{Zn}_{1/3}\text{Nb}_{2/3})\text{O}_3]:x[\text{PbTiO}_3]$ crystals into flippers is a design and fabrication approach in which the crystals are preloaded and reinforced so as to minimize exposure to tensile stresses, which could break them. The essence of this approach is to place the piezoelectric crystals in each actuator under a compressive preload along the fore-and-aft axis and to bond tapes of uniaxial carbon fibers to the outer surfaces of the crystals to minimize lateral tensile strain in each crystal (see Figure 1). By minimizing tensile strains in the crystals, one minimizes crystal damage, thereby minimizing the probability of actuator failure.

The prototype AFC system includes not only flippers but also flipperon-displacement position sensors, a power subsystem, and a control subsystem. For initial tests, the flippers were installed on the upper surface of a standard airfoil (wing) model at the flap hinge (see Figure 2). The model was mounted in a low-speed wind tunnel at the University of Arizona, where the tests were performed. The tests included measurements of customary aerodynamic-performance parameters (e.g., coefficients of lift and drag) at various angles of attack and airspeeds. During these tests, the flippers were actuated at various amplitudes, frequencies, and phases.

The tests showed that with appropriate actuation of flippers, lift was increased and drag reduced, by amounts of the order of a percent. Data from these tests were then used to estimate the benefits that could be obtained by adding flipperon-based AFC systems to

transport airplanes in two tests cases. In one case, it was found that the addition of the flippers to the vertical stabilizer of a Boeing 777 (or equivalent) airplane would make it possible to reduce the size of the vertical stabilizer, thereby reducing the drag, by an amount sufficient to enable a reduction of fuel consumption by as much as 1.7 percent. In another case, it was found that by exploiting the ability of a flipperon-based AFC system to delay the onset of stall, one could safely increase the angle of attack (thereby increasing lift) while reducing the size of the wings (thereby reducing the weight) of a blended-wing/body airplane by an amount sufficient to enable a reduction of fuel consumption by as much as 0.6 percent.

*This work was done by James H. Mabe of The Boeing Co. for Langley Research Center. Further information is contained in a TSP (see page 1).
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❁ System Estimates Radius of Curvature of a Segmented Mirror

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A system that estimates the global radius of curvature (GRoC) of a segmented telescope mirror has been developed for use as one of the subsystems of a larger system that exerts precise control over the displacements of the mirror segments. This GRoC-estimating system, when integrated into the overall control system along with a mirror-segment-actuation subsystem and edge sensors (sensors that measure displacements at selected points on the edges of the segments), makes it possible to control the GRoC mirror-deformation mode, to which mode contemporary edge sensors are insufficiently sensitive.

This system thus makes it possible to control the GRoC of the mirror with sufficient precision to obtain the best possible image quality and/or to impose a required wavefront correction on incoming or outgoing light.

In its mathematical aspect, the system utilizes all the information available from the edge-sensor subsystem in a unique manner that yields estimates of all the states of the segmented mirror. The system does this by exploiting a special set of mirror boundary conditions and mirror influence functions in such a way as to sense displacements in degrees of freedom that would other-

wise be unobservable by means of an edge-sensor subsystem, all without need to augment the edge-sensor system with additional metrological hardware. Moreover, the accuracy of the estimates increases with the number of mirror segments.

This work was done by John Rakoczy of Marshall Space Flight Center.

This invention has been patented by NASA (U.S. Patent No. 7,050,161). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-31807-1.